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10.

ON AN

IMPROVED OPTOMETER FOR ESTIMATING THE DEGREE OF ABNORMAL REGULAR ASTIGMATISM.

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At the solicitation of a large number of ophthalmic surgeons, both in this country and abroad, I am induced to publish an account of an optometer that I have been in the habit of using both in hospital and private practice during the last four years, for the purposes of determining the existence of abnormal regular astigmatism, and of estimating its degree.

Such being the primary object of this communication, I need not consider categorically the symptoms that attend this remarkable anomaly of refraction; but I shall explain, as briefly as possible, the optical conditions on which it depends, in order that the principles upon which the instrument is constructed may be better understood.

What is called regular astigmatism, or simply astigmatism, exists when the refracting surface of the cornea, instead of being practically spherical, presents an appreciable difference of curvature in its two principal meridians. These principal meridians, which usually approach, but rarely exactly coincide with, the vertical and horizontal meridians of the eyeball, are always at right angles to one another, and are designated the meridians of minimum or maximum curvature, or of least or greatest refraction, according as they represent segments of a larger or smaller ellipse. But although there is a difference of curvature between the two principal meridians as compared with each other, the curvature throughout the whole extent of any given meridian remains constant and unbroken. In an eyeball so formed there are therefore two foci—an anterior one for rays contained in the plane of the meridian of maximum curvature, and a posterior one for rays contained in the plane of minimum curvature. For these reasons radiating lines described on a plane perpendicular to the visual axis cannot all be seen clearly and distinctly at the same distance, inasmuch as when the rays passing through the meridian of maximum curvature, or greatest refraction, are focussed on the retina, those passing through the meridian of minimum curvature towards the posterior focus are intercepted, and form a blurred diffusion-image. When, on the other hand, the rays contained in the meridian of minimum curvature, or of least refraction, have their focus on the retina, those passing through the meridian of maximum curvature will, after converging at the anterior focus, cross each other and form an inverted diffusion-image. So, also, a point of light can never be focussed on the retina as a point, but forms a diffusion-image, which varies in shape, direction, and extent, with the distance of the object, and the state of accommodation; being at one time linear, at another elliptical, and at another perhaps circular. It is, indeed, this very peculiarity which is expressed in the term astigmatism.

In order to get rid of the inconveniences of these errors of refraction, it will be necessary to bring the two foci of the eye to the same plane, either by throwing the anterior one backwards by means of a diverging lens, or bringing the posterior one forwards by means of a converging lens. It is evident, however, that a spherical lens will not do this, because it refracts equally in all meridians; but, happily, as Sir George Airy has pointed out, a cylindrical lens will (a lens being so named because it is a segment of a cylinder, and refracts only those rays that fall at right angles to its axis, which is itself plane). If, then, the anterior focus is at the retina, a convex cylindrical lens will be required to produce sufficient convergence of the rays contained in the plane of the meridian of minimum curvature to bring the posterior one forwards; but if the posterior focus fall naturally on the retina, a concave cylindrical lens must be used to remove the point of convergence of the rays contained in the meridian of maximum curvature backwards to the retina. In the former instance there would be simple hypermetropic astigmatism,

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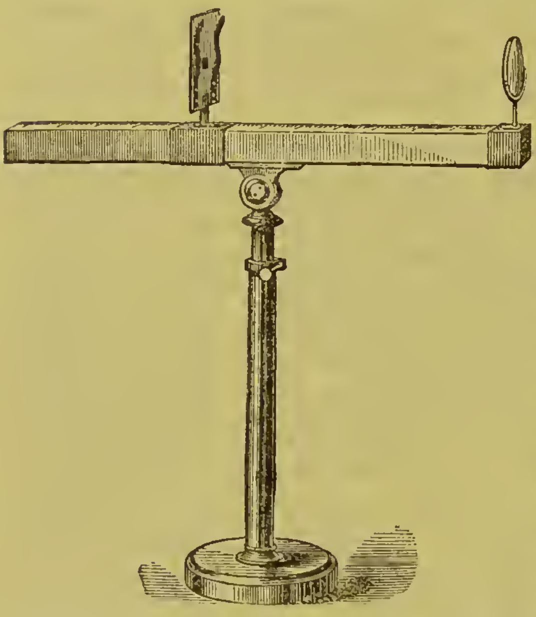
the meridian of maximum curvature being emmetropic in refraction, that of minimum curvature being hypermetropic; in the latter there would be simple myopic astigmatism, the meridian of minimum curvature being emmetropic, that of maximum curvature myopic. But, not unfrequently both meridians are hypermetropic or myopic, but of different degrees, and, more rarely, one meridian is myopic and the other meridian hypermetropic. In any of these complications a simple cylindrical lens will fail to correct the whole of the ametropia, a spherical lens being required in addition to give normal acuteness of vision. The association of other errors of refraction with astigmatism does not, however, as will be seen further on, materially increase the difficulties of finding suitable glasses.

Before describing the mode of using the optometer, it may be well to premise that the principle upon which it is based is to find, first, the distance at which a line is seen clearly in the meridian of least refraction or minimum curvature, and then, by means of a suitable concave cylindrical lens placed at right angles to the line so seen, to throw back the focus of the meridian of greatest refraction or maximum curvature on to the retina, and thereby to give definition in that meridian also.

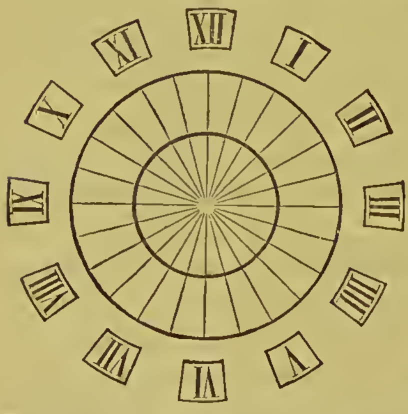
FIG. 1.



From what has been stated above it will be readily understood that the meridian of minimum curvature will, in cases of simple myopic astigmatism, be emmetropic; of simple hypermetropic or of mixed astigmatism, it will be hypermetropic; while in cases of compound astigmatism it will be the most hypermetropic or the least myopic.

The instrument consists of a stout horizontal bar one foot and a half in length, divided on its upper surface into inches and tenths, and fixed to a vertical telescopic stem. Surmounting the rod is a sliding metal plate, to which is attached a card bearing the figure of a dial with fine radiating lines describing angles of fifteen degrees with each other. At the proximal end of the rod a semicircular clip is placed, having degrees corresponding with those of the lines on the dial marked on its margins. The use of this clip is to hold the cylindrical lens employed to correct the astigmatism, and the marks of the degrees on the side show the exact position in which the axis of the lens should be placed.

FIG. 2.



The card here represented is a copy of that first suggested by Javal, and is the form that I most frequently, but by no means always, employ. For the majority of persons, especially in hospital practice, it is undoubtedly the simplest and the best, since patients under examination have, as it were, merely "to tell the time" as from an ordinary dial. In some cases, other figures of various shapes may be used with advantage; indeed, there need be no limit to the variety of designs.

To use the instrument properly, the following instructions must be strictly and exactly followed:—

1st. The eye about to be examined, having previously been put completely under the influence of atropine, should be made artificially short-sighted to about $M = \frac{1}{8}$ to $\frac{1}{10}$ by means of a strong convex lens placed in a spectacle-frame, and the opposite eye excluded by an opaque disc. The patient should then sit down before the optometer, the height of which has been properly adjusted, place the eye with the lens before it, as close as possible to the semicircular clip, and with the head erect look straight in front at the radiating lines on the dial. The focal length of the lens necessary to produce the myopia will depend upon the state of refraction. For ordinary purposes $+\frac{1}{5}$ is sufficient, but if there be a high degree of hypermetropia $+\frac{1}{3}$ or even $\frac{1}{2}$ may be required, whereas if there be myopia a much weaker lens than $+\frac{1}{5}$ will suffice; and if the degree be high, the lens need not perhaps be stronger than $+\frac{1}{20}$ or $\frac{1}{40}$.

2nd. The dial, having then been placed beyond the point of distinct vision, should be gradually approximated along the bar until at least one of the lines is clearly and distinctly seen. This line will, of course, be focussed in the meridian of minimum curvature or least refraction, because it is seen at the greatest distance. After this the dial must on no account be moved, but its distance from the eye accurately noted.

3rd. If all the radiating lines have come into view with equal clearness at or about the same time there is little or no astigmatism; but if whilst one line is clearly seen that at right angles to it is blurred or altogether invisible, there is astigmatism which may be corrected by placing in the semicircular clip a suitable concave cylindrical lens with its axis parallel to the blurred line, or perpendicular to that first clearly seen. The concave cylindrical lens which corrects the astigmatism will be the weakest, which, so placed, renders the blurred line as clear as that originally well seen; and the focal length of the glass will exactly represent the degree of astigmatism.

From the results of this examination, the stages of which are the same in every instance, the degree and the direction of astigmatism, as well as the presence or absence of the other forms of ametropia, may be readily determined.

From (2) we learn (*a*) the direction of the two principal meridians of maximum and minimum curvature; (*b*) the presence or absence of hypermetropia, or myopia, in the principal meridian of minimum curvature, and the degree; (*c*) the presence or absence of astigmatism together with its direction; and by (3) we ascertain the degree of astigmatism.

(*a*) Since by a law of physical and physiological optics the definition of any line depends upon a due adjustment of the meridian of the eye at right angles to it, we know that the principal meridian of minimum curvature is at right angles to the line clearly seen at the greatest distance; and as the two principal meridians of the eye in regular astigmatism are always practically perpendicular to one another, we may be equally sure that the principal meridian of maximum curvature exactly corresponds in direction with the clear line.

(*b*) The presence or absence of hypermetropia or myopia in the principal meridian of minimum curvature may be determined by observing the point at which the line is first clearly seen; if this meridian be emmetropic, the line will be seen exactly at the distance of the focal length of the lens employed to produce the artificial myopia; if hypermetropic, beyond; if myopic, within that distance.

If there be ametropia in this meridian, we may readily calculate its degree by the following formula:—

$$x = \frac{1}{d} - \frac{1}{f}$$
$$= \frac{f - d}{f\,d}$$

x representing the degree of ametropia, $\frac{1}{f}$ the focal length of the lens used to make the eye myopic, $\frac{1}{d}$ the greatest distance of distinct vision. Giving the calculation in words, it may be thus stated: the refraction equals the focal length of the lens minus the greatest distance at which a line is clearly seen, divided by the multiple of these numbers.

To illustrate this, let it be supposed that the lens is $+\frac{1}{5}$, the greatest distance at which a line—say the vertical—is clearly seen ten inches, then there will be hypermetropia in the horizontal meridian of $= \frac{10 - 5}{10 \times 5} = \frac{1}{10}$, because the line is seen at a distance greater than the focal length of the lens.

If the lens be $+\frac{1}{10}$, and the greatest distance at which a line—say the vertical in this instance also—is clearly seen be five inches, there will be myopia in the horizontal meridian of $= \frac{10-5}{10 \times 5} = \frac{1}{10}$, because the distance at which the line is seen is less than the focal length of the lens.

(*c*) If astigmatism exists, all the radiating lines will not be clearly seen at the same point, and as the line seen at the greatest distance is defined in the meridian of minimum curvature, the blurred line will be at right angles to the meridian of greatest curvature, which by this mode of examination is regarded as the astigmatic meridian. The direction of these lines, therefore, at once indicates the direction of the astigmatism.

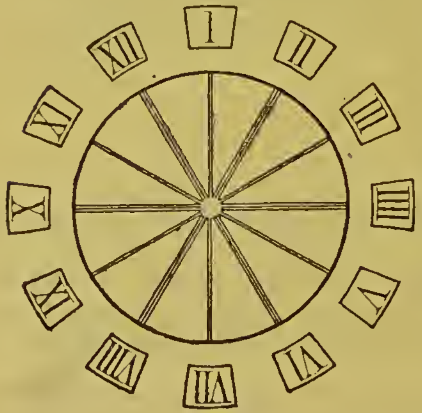
All that will be now required to correct the astigmatism—that is, to make the refraction of the two principal meridians equal—will be to place in the semicircular clip the weakest concave cylindrical lens which, with its axis at right angles to the clear line, makes the blurred one equally clear. This lens will have the further effect of improving all the intermediate lines of the dial, if indeed it do not render them at once absolutely clear.

To order suitable glasses will now be an easy matter, all that is necessary being to combine the cylindrical lens with the spherical that in the second stage of the examination was found to represent the refraction of the meridian of minimum curvature. For instance, if in the first of the supposed cases a concave cylindrical lens $= \frac{1}{20}$, with its axis horizontal, were the weakest which made the horizontal line as clear as the vertical, then would As $= \frac{1}{20}$, and the hypermetropia in the vertical meridian would, therefore, be exactly $\frac{1}{10} - \frac{1}{20} = \frac{1}{20}$. The combination required to correct the ametropia would, therefore, be: spherical $+\frac{1}{10}$ cylindrical $-\frac{1}{20}$ axis horizontal. But if a concave cylinder of $= \frac{1}{10}$ were the weakest that made the horizontal line clear, then there would be no hypermetropia in the vertical meridian, and the case would be one of simple hypermetropic astigmatism $= \frac{1}{10}$ in horizontal meridian. In such a case, a convex cylindrical lens $= \frac{1}{10}$, with its axis vertical, would be indicated. If, on the other hand, a concave cylinder $= \frac{1}{8}$ were the weakest which made the horizonal line clear, there would be mixed astigmatism: with myopia $= \frac{1}{10} - \frac{1}{8} = \frac{1}{40}$ in the vertical meridian, and hypermetropia $= \frac{1}{10}$ in the horizontal meridian; and the glasses necessary would be sp $+\frac{1}{10}$ cy $-\frac{1}{8}$ axis horizontal.

If, in the second of the above cases, a concave cylinder $= \frac{1}{20}$ made the horizontal line clear, then there would be myopia in the vertical meridian $= \frac{1}{10} + \frac{1}{20} = \frac{3}{20} = \frac{1}{7}$ (nearly); and the ametropia would be corrected by sp $-\frac{1}{10}$ cy $-\frac{1}{20}$, with axis horizontal.

I may state that this instrument—which I have now used with gratifying results in nearly three hundred cases of astigmatism, and which is, I believe, largely employed by many others—is made by Swift, of University-street, W.C.

FIG. 3.



Postscript.—The accompanying figure may be sometimes advantageously substituted for that with single lines. If a patient can readily count the number of lines, vision for those lines is clear and distinct. To ensure accuracy the figure may be turned, so that the lines at first vertical shall become horizontal.

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